HØGSKOLEN I AGDER
Fakultet for teknologi

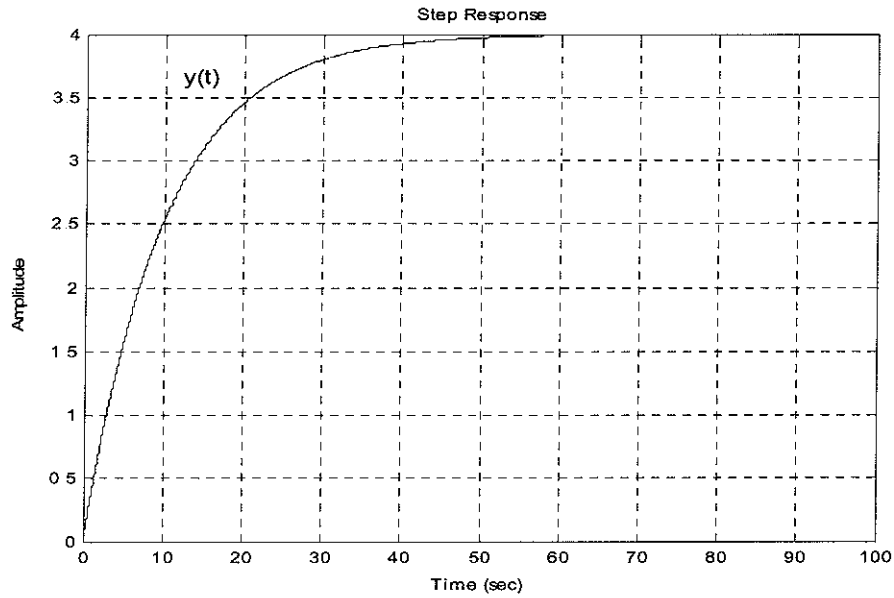
E K S A M E N S O P P G A V E

EMNE: ENE 103/MAS 107 – Reguleringsteknikk
FAGLÆRER: W. Bartholdsen

Klasse(r):	**Dato: 10.06.05**	**Eksamenstid, fra-til: 0900-1300**	
Eksamensoppgaven består av følgende	**Antall sider: 9 inkl. forside**	**Antall oppgaver: 7**	**Antall vedlegg: 2**
Tillatte hjelpemidler er:	**Kalkulator**		
KANDIDATEN MÅ SELV KONTROLLERE AT OPPGAVESETTET ER FULLSTENDIG			

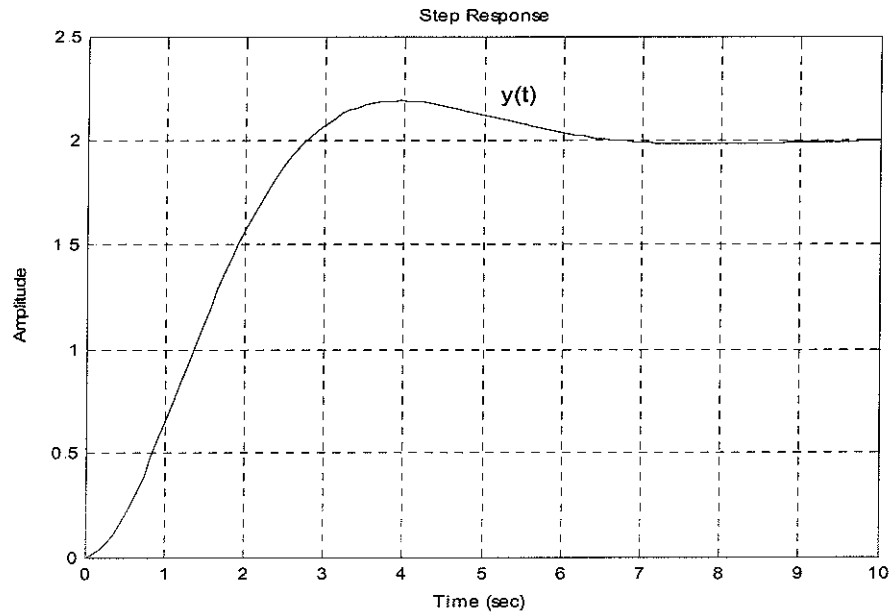
Oppgave 1.

Bestem transferfunksjon $h(s) = \frac{y(s)}{u(s)}$ for u(t) = 2(sprang):



Oppgave 2.

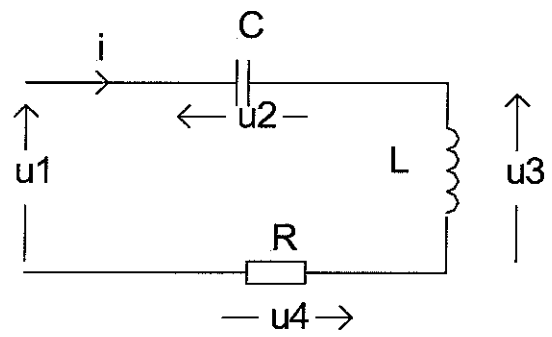
$u(t) = 1$ (sprang):



Bestem transferfunksjon $h(s) = \frac{y(s)}{u(s)}$

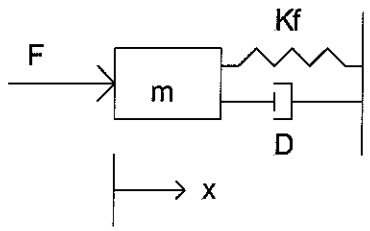
Oppgave 3.

Bestem transferfunksjon $h(s) = \frac{u_3(s)}{u_1(s)}$ for:



Systemet er energiløst i starten: $u_2(0) = u_3(0) = u_4(0) = 0$
$R = 10[\Omega], L = 0{,}01[H]$ *og* $C = 10^{-6}[F]$

Oppgave 4.



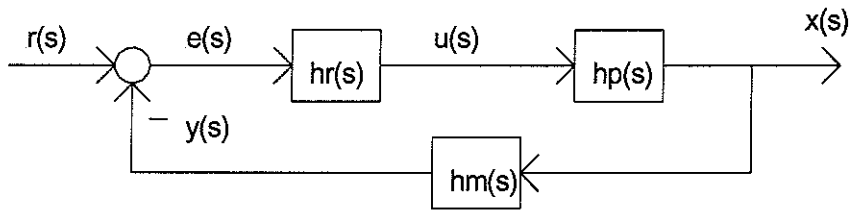
$m = 100[kg], D = 100$ *og* $K_f = 25$

Skisser matematisk blokkdiagram for x(t) når $x(0) = \dot{x}(0) = \ddot{x}(0) = 0$.

Oppgave 5.

Skisser Bodeplot for $h(s) = \frac{10}{s^2 + s} \cdot e^{-s}$.
For beregninger velg: $\omega = 0{,}01\ ,\ 0{,}1\ ,\ 1{,}0$ *og* 10

Oppgave 6.



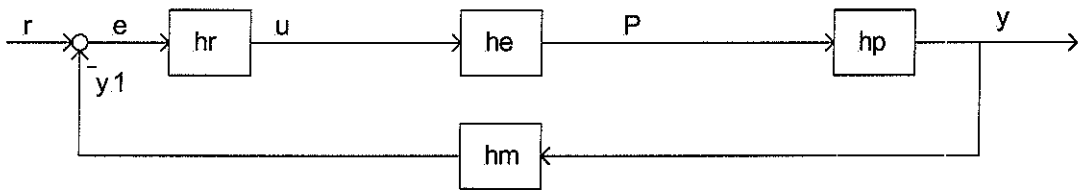
$$u(t) = u(0) + K_P \cdot e(t) + \frac{K_P}{T_I}\int e(t)dt = 4e(t) + \int e(t)dt$$

$$8\ddot{x}(t) + 6\dot{x}(t) + x(t) = u(t)$$

$$y(t) = x(t)$$

Bestem reguleringssystemets totale transferfunksjon $h(s) = \frac{x(s)}{r(s)}$ på enkleste form.

Oppgave 7.



$$h_e(s) = \frac{100}{0{,}1s + 1}$$

$$h_p(s) = \frac{1}{10s + 1}$$

$$h_m(s) = \frac{1}{s + 1}$$

$$h_r(s) = K_P + \frac{K_P}{T_i \cdot s} + K_P T_d s^2$$

Innstilling av regulator skal foregå etter Ziegler-Nichols metode.
Bestem K_{Pk} og T_k.

(Tips: $h_r(s) = K_{Pk}, |h_0(j\omega_{180})| = 1\ og\ \angle h_0(j\omega_{180}) = -\pi$)

Vedlegg 1 – Eksamen – Reguleringsteknikk.

Nr	F(s)	f(t)	
01	1	$\delta(t)$	Enhetsimpuls
02	$e^{-\varpi}$	$\delta(t-\tau)$	Forsinket enhetsimpuls
03	$\frac{1}{s}$	1(t)	Enhetssprang
04	$\frac{1}{s}e^{-\varpi}$	$1(t-\tau)$	Forsinket enhetssprang
05	$\frac{1-e^{-\varpi}}{s}$	1(t)-1(t-τ)	Enhetspuls
06	$\frac{1}{s^2}$	t(t)	Enhetsramp
07	$\frac{1}{s^2}e^{-\varpi}$	t(t-τ)	Forsinket enhetsramp
08	$\frac{2}{s^3}$	$t^2(t)$	Enhetsparabel
09	$\frac{1}{s^n}$	$\frac{t^{n-1}}{(n-1)!}$	n = 1 , 2 , 3 , ... 0! = 1
10	$\frac{1}{\sqrt{s}}$	$\frac{2}{\sqrt{\pi \cdot t}}$	
11	$\frac{1}{\sqrt{s^3}}$	$\frac{2\sqrt{t}}{\sqrt{\pi}}$	
12	$\frac{1}{s^{(n+0.5)}}$	$\frac{2^n \; t^{(n-0.5)}}{1 \; 3 \; 5 \; ..... \; (2n-1) \; \sqrt{\pi}}$	n = 1 , 2 , 3 , ... 0! = 1
13	$\frac{1}{Ts+1}$	$\frac{1}{T} \cdot e^{-\frac{t}{T}}$	Impulsrespons for 1.orden system
14	$\frac{1}{(Ts+1)^2}$	$\frac{t}{T^2} \cdot e^{-\frac{t}{T}}$	
15	$\frac{1}{(Ts+1)^n}$	$\frac{t^{(n-1)}}{T^n(n-1)!} \cdot e^{-\frac{t}{T}}$	n = 1 , 2 , 3 , ... 0! = 1
16	$\frac{s}{Ts+1}$	$\frac{1}{T}\delta(t) - \frac{1}{T^2} \; e^{-\frac{t}{T}}$	
17	$\frac{T_2 s+1}{T_1 s+1}$	$\frac{T_2}{T_1}\delta(t) - \frac{T_2 - T_1}{T_1^2} \; e^{-\frac{t}{T_1}}$	
18	$\frac{1}{s(Ts+1)}$	$1-e^{-\frac{t}{T}}$	Sprangrespons for 1.orden system

Nr	F(s)	f(t)
19	$\frac{T_2 s+1}{s(T_1 s+1)}$	$1+\frac{T_2-T_1}{T_1}\ e^{-\frac{t}{T_1}}$
20	$\frac{1}{s^2(Ts+1)}$	$t-T+T\cdot e^{-\frac{t}{T}}$
21	$\frac{1}{s(Ts+1)^2}$	$1-(1+\frac{t}{T})\cdot e^{-\frac{t}{T}}$
22	$\frac{T_2 s+1}{s^2(T_1 s+1)}$	$1+(\frac{T_2-T_1}{T_1^2}\ t-1)\cdot e^{-\frac{t}{T_1}}$
23	$\frac{1}{(T_1 s+1)(T_2 s+1)}, T_1 \neq T_2$	$\frac{1}{T_1-T_2}\cdot(e^{-\frac{t}{T_1}}-e^{-\frac{t}{T_2}})$
24	$\frac{s}{(T_1 s+1)(T_2 s+1)}, T_1 \neq T_2$	$\frac{1}{T_2-T_1}\ (\frac{1}{T_1}e^{-\frac{t}{T_1}}-\frac{1}{T_2}e^{-\frac{t}{T_2}})$
25	$\frac{T_3 s+1}{(T_1 s+1)(T_2 s+1)}, T_1 \neq T_2$	$\frac{1}{T_1-T_2}\ (\frac{T_1-T_3}{T_1}e^{-\frac{t}{T_1}}-\frac{T_2-T_3}{T_2}e^{-\frac{t}{T_2}})$
26	$\frac{1}{s(T_1 s+1)(T_2 s+1)}, T_1 \neq T_2$	$1-\frac{1}{T_1-T_2}\cdot(T_1 e^{-\frac{t}{T_1}}-T_2 e^{-\frac{t}{T_2}})$
27	$\frac{T_3 s+1}{s(T_1 s+1)(T_2 s+1)}, T_1 \neq T_2$	$1-\frac{T_1-T_3}{T_1-T_2}e^{-\frac{t}{T_1}}+\frac{T_2-T_3}{T_1-T_2}e^{-\frac{t}{T_2}}$
28	$\frac{1}{(T_1 s+1)(T_2 s+1)(T_3 s+1)}$ $T_1, T_2, T_3 \neq$	$\frac{T_1\cdot e^{-\frac{t}{T_1}}}{(T_1-T_2)(T_1-T_3)}+\frac{T_2\cdot e^{-\frac{t}{T_2}}}{(T_2-T_1)(T_2-T_3)}+\frac{T_3\cdot e^{-\frac{t}{T_3}}}{(T_3-T_1)(T_3-T_2)}$
29	$\frac{s}{(T_1 s+1)(T_2 s+1)(T_3 s+1)}$ $T_1, T_2, T_3 \neq$	$\frac{e^{-\frac{t}{T_1}}}{(T_1-T_2)(T_3-T_1)}+\frac{e^{-\frac{t}{T_2}}}{(T_2-T_3)(T_1-T_2)}+\frac{e^{-\frac{t}{T_3}}}{(T_3-T_1)(T_2-T_3)}$
30	$\frac{T_4 s+1}{(T_1 s+1)(T_2 s+1)(T_3 s+1)}$ $T_1, T_2, T_3 \neq$	$\frac{(T_1-T_4)\cdot e^{-\frac{t}{T_1}}}{(T_1-T_2)(T_1-T_3)}+\frac{(T_2-T_4)\cdot e^{-\frac{t}{T_2}}}{(T_2-T_1)(T_2-T_3)}+\frac{(T_3-T_4)\cdot e^{-\frac{t}{T_3}}}{(T_3-T_1)(T_3-T_2)}$
31	$\frac{1}{s(T_1 s+1)(T_2 s+1)(T_3 s+1)}$ $T_1, T_2, T_3 \neq$	$1-\frac{T_1^2\ e^{-\frac{t}{T_1}}}{(T_1-T_2)(T_1-T_3)}-\frac{T_2^2\cdot e^{-\frac{t}{T_2}}}{(T_2-T_1)(T_2-T_3)}+\frac{T_3^2\ e^{-\frac{t}{T_3}}}{(T_3-T_1)(T_3-T_2)}$
32	$\frac{T_4 s+1}{s(T_1 s+1)(T_2 s+1)(T_3 s+1)}$ $T_1, T_2, T_3 \neq$	$1-\frac{T_1(T_1-T_4)\cdot e^{-\frac{t}{T_1}}}{(T_1-T_2)(T_1-T_3)}-\frac{T_2(T_2-T_4)\cdot e^{-\frac{t}{T_2}}}{(T_2-T_1)(T_2-T_3)}-\frac{T_3(T_3-T_4)\cdot e^{-\frac{t}{T_3}}}{(T_3-T_1)(T_3-T_2)}$

Nr	F(s)	f(t)
33	$\frac{\omega_0^2}{s^2+2\zeta\omega_0 s+\omega_0^2}$	$\frac{\omega_0}{\sqrt{1-\zeta^2}}\cdot e^{-\omega_0\zeta t}\ \sin(\omega_0\cdot\sqrt{1-\zeta^2}\cdot t),\ (0\langle\zeta\langle 1)$
34	$\frac{s}{s^2+2\zeta\omega_0 s+\omega_0^2}$	$e^{-\omega_0\zeta t}\ (\cos\omega t-\frac{\zeta}{\sqrt{1-\zeta^2}}\sin\omega t)$ $\omega=\omega_0\sqrt{1-\zeta^2},\ (0\langle\zeta\langle 1)$
35	$\frac{\omega_0^2}{s(s^2+2\zeta\omega_0 s+\omega_0^2)}$	$1-\frac{1}{\sqrt{1-\zeta^2}}e^{-\omega_0\zeta t}\ \cos(\omega t-\sin^{-1}\zeta)$ $\omega=\omega_0\sqrt{1-\zeta^2},\ (0\langle\zeta\langle 1)$
36	$\frac{\omega}{s^2+\omega^2}$	$\sin\omega t$
37	$\frac{s}{s^2+\omega^2}$	$\cos\omega t$
38	$\frac{1}{s(s^2+\omega^2)}$	$\frac{1}{\omega^2}(1-\cos\omega t)$
39	$\frac{Ts+1}{s^2+\omega^2}$	$\sqrt{1+\frac{1}{(\omega T)^2}}\ \sin(\omega t+tg\omega T)$
40	$\frac{Ts+1}{s(s^2+\omega^2)}$	$\frac{1}{\omega^2 T}-\frac{\sqrt{1+\frac{1}{(\omega T)^2}}}{\omega}\ \cos(\omega t+tg\omega T)$
41	$\frac{s\ \sin\phi+\omega\cdot\cos\phi}{s^2+\omega^2}$	$\sin(\omega t+\phi)$
42	$\frac{s\ \cos\phi+\omega\cdot\sin\phi}{s^2+\omega^2}$	$\cos(\omega t+\phi)$

Vedlegg 2 – Eksamen – Reguleringsteknikk.

$$w[\frac{kg}{s}] = \rho[\frac{kg}{m^3}] \cdot q[\frac{m^3}{s}]$$

$$V[m^3] = A[m^2] \cdot x[m]$$

$$q[\frac{m^3}{s}] = k_1[\frac{m^3}{s \cdot \sqrt{Pa}}] \cdot \sqrt{\Delta p[Pa]}$$

$$\Delta q \approx k_2[\frac{m^2}{s}] \cdot \Delta x[m]$$

$$p_S[Pa] = \rho[\frac{kg}{m^3}] \cdot g[\frac{m}{s^2}] \cdot x[m]$$

$$m[kg] = \rho[\frac{kg}{m^3}] \cdot V[m^3]$$

$$E[J = W \cdot s] = c[\frac{J}{kg \cdot {}^{o}C}] \cdot m[kg] \cdot T[^{o}C]$$

$$Q_1[W] = c[\frac{J}{kg \cdot {}^{o}C}] \cdot w[\frac{kg}{s}] \cdot T_1[^{o}C]$$

$$Q_2[W] = h[\frac{W}{{}^{o}C}] \cdot (T_2 - To)[^{o}C]$$

$$F_a[N] = m[kg] \cdot a[\frac{m}{s^2}]$$

$$F_f[N] = K[\frac{kg}{s^2}] \cdot x[m]$$

$$F_d[N] = D[\frac{kg}{s}] \cdot v[\frac{m}{s}]$$

$$M_a[\frac{kg \cdot m^2 \cdot rad}{s}] = J[kg \cdot m] \cdot \omega[\frac{rad}{s}]$$

$$T_d[N \cdot m] = D[\frac{N \cdot m \cdot s}{rad}] \cdot \omega[\frac{rad}{s}]$$

$$T_f[N \cdot m] = K[\frac{N \cdot m}{rad}] \cdot \theta[rad]$$

$$u_R[V] = i_R[A] \cdot R[\Omega]$$

$$u_L[V] = L[H] \cdot \frac{d}{dt} i_L[A]$$

$$u_C[V] = \frac{1}{C[F]} \int i_C[A]dt$$

$$\lim_{t\to 0} y(t) = \lim_{s\to\infty}[s \cdot y(s)]$$
$$\lim_{t\to\infty} y(t) = \lim_{s\to 0}[s \cdot y(s)]$$

$$\frac{dx}{dt} \approx \frac{x(k) - x(k-1)}{T_S}$$
$$\left[\dot{x}\right] = [A][x] + [B]u$$
$$[y] = [D][x]$$
$$h(s) = \frac{K \cdot \omega_0^2}{s^2 + 2 \cdot \zeta \cdot \omega_0 \cdot s + \omega_0^2}$$
$$\zeta \geq 1 : p_{1,2} = -\omega_0\zeta \pm \omega_0\sqrt{\zeta^2 - 1}, \quad 0 < \zeta < 1 : p_{1,2} = -\omega_0\zeta \pm j\omega_0\sqrt{1-\zeta^2}$$
$$\delta = \frac{y_{\max} - y_s}{y_s} = e^{-\frac{\pi\cdot\zeta}{\sqrt{1-\zeta^2}}}$$
$$T_r \approx \frac{1{,}5}{\omega_0} \approx \sum_i T_{r\,i}$$
$$T_{\max} = \frac{\pi}{\omega_0\sqrt{1-\zeta^2}}$$

$$x[dB] = 20\log_{10} x$$
$s = j\omega$:
$$|h_1(j\omega)| = |e^{-j\,\omega\cdot\tau}| = 1, \quad \angle h_1(j\omega) = -\omega\tau$$
$$|h_2(j\omega)| = |(j\omega)^n| = \omega^n, \quad \angle h_2(j\omega) = n\frac{\pi}{2}$$
$$|h_3(j\omega)| = \left|\left(\frac{1}{j\omega}\right)^n\right| = \frac{1}{\omega^n}, \quad \angle h_3(j\omega) = -n\frac{\pi}{2}$$
$$|h_4(j\omega)| = |j\omega T + 1| = \sqrt{\omega^2 T^2 + 1}, \quad \angle h_4(j\omega) = tg^{-1}(\omega T)$$
$$|h_5(j\omega)| = \left|\left(\frac{1}{j\omega T + 1}\right)\right| = \frac{1}{\sqrt{\omega^2 T^2 + 1}}, \quad \angle h_5(j\omega) = -tg^{-1}(\omega T)$$

$$|h_6(j\omega)| = \left|\left(\frac{\omega_0^2}{(j\omega)^2 + 2\cdot\zeta\cdot\omega_0\cdot j\omega + \omega_0^2}\right)\right| = \frac{1}{\sqrt{(1-\frac{\omega^2}{\omega_0^2})^2 + (2\zeta\frac{\omega}{\omega_0})^2}}, \angle h_6(j\omega) = -tg^{-1}\left(\frac{2\zeta\frac{\omega}{\omega_0}}{1-\frac{\omega^2}{\omega_0^2}}\right)$$

$$\omega_r = \omega_0\sqrt{1-2\zeta^2}$$
$$\left|\frac{R}{K}\right| = \frac{1}{2\zeta\sqrt{1-\zeta^2}}$$
$$\omega_b = \omega_0\sqrt{1-2\zeta^2+\sqrt{4\zeta^4-4\zeta^2+2}}$$